Ubiquitous Broadband Deployment and the Coming of Always-on Wireless Access

NORTEL NETWORKS™

Nortel Networks is an industry leader and innovator focused on transforming how the world communicates and exchanges information. The company provides high-performance network infrastructure and technology to service providers and enterprises.

As a global leader in delivering affordable, intelligent, reliable multimedia networks with the flexibility to provide the next generation of broadband services, Nortel Networks is in a unique position to understand broadband issues from multiple perspectives.

Today, the company is working to realize its vision of networks that offer infinite bandwidth-on-demand and always-on wireless access, leveraging its expertise in data, voice, wireless, and metro-and-backbone optical networking and its unparalleled understanding of how optical, wireline, and wireless networks must work together as they converge.

This document provides an overview of the benefits of broadband services to individuals and businesses and looks at the public policy, investment, and supply-and-demand factors affecting the deployment of broadband technology. It details the enabling technologies now making ubiquitous broadband a viable opportunity, as well as the shape of communications to come.

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- Building networks that can provide people with substantially more communications capacity — more bandwidth — is now a front-and-center issue.
- Broadband must be viewed holistically, as a functionality, rather than a platform, which can be delivered by a number of technologies.
- Effective broadband must encompass both wireline and wireless access, deliver bandwidth from end to end, and provide valuable applications and exemplary user experiences.
- Broadband is also about reliability, support, and security to promote the trust and confidence necessary to elevate broadband use to a fundamental element of society.
- A global consensus has emerged that ubiquitous broadband, wired and wireless, will be good for the global economy, have significant benefits for consumers and businesses, and will expand markets, enable new business models, and drive new investments.
- While ubiquitous broadband service should be tested in the crucible of a competitive marketplace, some countries are promoting broadband deployment through national policies in an effort to capture economic and social benefits.
- Government policies affecting broadband deployment should be technology neutral and crafted in such a way as to not inadvertently create disincentives to investment nor increase the economic risk in a competitive environment.
- There are high costs associated with broadband infrastructure, both for the carriers deploying it and the technology companies creating it.
- Industry must lead the way in making the necessary network investments based primarily on the opportunity to make a reasonable return on those investments.
- Demand for ubiquitous broadband access is increasing with the expanding needs of residential consumers, small-to-medium-sized enterprises, and mobile consumers.
- Ubiquitous broadband has become a viable opportunity because many developments underpinning its deployment are converging, such as advances in network cost performance, digitization and storage, carrier-grade networks, network intelligence, and access appliances.
- Network evolution has been accelerating for years as the Internet and fiber-optic, data, wireless, cable, and satellite networks spread rapidly around the world.
- Faster broadband deployment is required so more businesses can harness information flows to help them innovate and reshape their operations.
- In the future, networks will provide affordable infinite bandwidth-on-demand and always-on wireless access, signaling a fundamental change in how networks deliver multimedia content and how people receive and interact with it.
- To move into the era of infinite bandwidth and always-on wireless access, many breakthroughs and investments will be needed in optical technology, high-spectrum communications, wireless, and high-performance network infrastructure.
- Ultimately, any amount of personalized information will be available in any form to any individual at any time and in any place, a development that will provide great value to national economies and global society.

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> The widespread deployment of broadband infrastructure has become the central communications policy objective today. It is widely believed that ubiquitous broadband deployment will bring valuable new services to consumers, stimulate economic activity, improve national productivity, and advance many other worthy objectives, such as improving education, and advancing economic opportunity.... It is now time for fewer words and more action.[1]
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> – Michael K. Powell, Chairman, Federal Communications Commission

How quickly can the world's communications-network providers make broadband service available to the mass market? Building networks that provide people with substantially more communications capacity — more bandwidth — is a front-and-center issue for many individuals, governments, and players in the global economy at the beginning of the 21st century.

The good news is the broadband debate has moved from the periphery of communication policy to being a "central communications policy objective." Policy makers, telecom leaders, and pundits across the political landscape are all talking about "ubiquitous broadband." Most are saying the same thing: it isn't coming fast enough.

Most also agree there's no quick fix for the broadband bottleneck. New technologies in communications media and networking take years to diffuse, especially when they require significant infrastructure investment. As Intel founder Andy Grove said, "Breaking the bandwidth bottleneck is like putting a man on the moon." More than technology is involved.

Debate so far has generally revolved around deploying "first-generation" broadband, technologies that will round out and complete the core network advances made over the past decade. These will provide the firepower for consumers to receive a wider range of useful services over the Internet. The question is how best to create bigger, better, wider, and faster-flowing channels to connect businesses and residences to the Net and to the other high-performance data networks built in the last half of the 1990s.

But is broadband just a fat and fast pipe? Is it just a speed? Should it be viewed, as FCC Chairman Powell has said, "holistically as a technical capability that can be matched to consumers' broad communication, entertainment, information, and commercial desires?"[2] Broadband is functionality rather than a platform, which can be delivered by a number of technologies.

For broadband to be truly effective, it must involve more than just high-speed Internet access. The common definition must be more holistic.

The definition of broadband has to encompass both wireline and wireless access, though always-on wireless access may still be some years in the future. The definition must include bandwidth availability from end to end, from the data center to the metro and core networks that allow a broadband service to be delivered, bandwidth that provides valuable applications and exemplary user experiences. All parts of the network must be designed and engineered to deliver that performance.

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[1] Press conference remarks, October 23, 2001.

[2] Remarks at the National Summit on Broadband Deployment, Washington, D.C., October 25, 2001.

The definition of broadband has to include the concept of being "always-on" since bandwidth has to be provided when it's needed. Broadband is also not just about bandwidth. It's about reliability, support, and security to promote the trust and confidence necessary to elevate broadband network use from a casual activity to a fundamental element of society.

To be useful and to deliver on the consumers' needs for communication, entertainment, information, and commerce, broadband needs to have a number of key attributes. If service is not reliable, if an individual's privacy is not protected, if information is vulnerable to hackers, or if access to desired material is unavailable due to congestion, then the usefulness of a broadband access pipe is minimal and does not deliver the economic benefits it has the potential to deliver.

The Broadband Consensus Today

As discussions and debate on broadband have progressed, a global consensus has emerged on some factors that are key to deploying the first generation of this technology.

All interested players have great expectations for ubiquitous broadband, wired and wireless. All agree that broadband — in the sense of faster and better access to the Internet — is important and that opening up the last-mile connection to homes and to small-to-medium-sized businesses is the most pressing issue in unclogging network communications worldwide.

All agree that a more rapid roll-out of broadband technologies will have a big impact on the economy and everyday life. Individuals, no matter where they live, will enjoy an overall improved quality of life, with greater access to economic opportunities and higher levels of education, health, and cultural experiences. Enterprises will be able to enhance their productivity and efficiency.

The precise size and shape of the impact are uncertain since the fundamental benefits of new technologies and their ultimate impact on society are always hard to predict. The benefits of electricity, the telephone, and mobile phones seemed not very promising initially, yet all these technologies led to remarkable changes in how people live and work and how businesses operate. Broadband networks are at a similar stage of development.

Widespread broadband deployment will clearly be good for national economies and the global economy. There will be significant benefits for consumers and, especially, businesses. The economic impact has been conservatively estimated to be in the order of $400 billion to half-a-trillion dollars in the U.S. alone as small-to-medium-size businesses gain new network tools to enhance their productivity and accelerate innovation.[3]

Several studies show how investment in networking has led to significant improvements in workforce productivity, boosting GDP and standards of living while reducing the overall cost of doing businesses (a U.S. government study estimated the cost of banking was 70 to 100 times cheaper on the Internet than in a branch and 20 to 30 times cheaper than through an ATM).[4] By delivering benefits such as these, investments in broadband will have a direct and positive economic impact.

Broadband deployment will expand markets and enable new business models. It will drive new investment in fields such as computer applications, entertainment, and online services. It will enable advanced health-related services, telecommuting, new ways for businesses to work virtually with suppliers, partners, and customers, and new forms of online entertainment and educational products. It will create an environment where new services can bloom.

The global consensus recognizes that there are several ways to make much more bandwidth available. Various technologies fulfill the technical requirements for bridging the "last-mile" gap between high-capacity networks and their users, both individuals and organizations. Each technology — fiber, cable, DSL, broadband wireless, and satellite — provides unique capabilities. Each has its advantages and disadvantages (*see* "Appendix: An Overview of Broadband Delivery Today" on page 23).

These technologies compete with each other, appealing to users on the basis of performance, price, quality of service, geography, user friendliness, customer service, and other factors. A mobile worker might value the benefits of a wireless broadband service over fixed solutions such as cable or DSL. A home-based employee would value the connectivity and speed provided by fixed broadband access.

In many countries, it's up to individuals and organizations to decide which of these access options serves them best, demonstrating by where they spend their money which provides them with the most valuable services at the best and most reasonable price. The winners in the marketplace will prevail.

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[3] Robert W. Crandall and Charles L. Jackson, *The $500 Billion Opportunity: The Potential Economic Benefit of Widespread Diffusion of Broadband Internet Access*, July 2001.

[4] U.S. Department of Commerce, *The Emerging Digital Economy*, April 1998.

The Role of Governments

Some argue broadband is too slow in coming and its arrival needs speeding up, perhaps through government action. Others believe first-generation broadband is being made available in a reasonable and timely manner and it's up to consumers in the marketplace to determine the rate of broadband adoption.

Many agree government has a constructive role to play in helping telecom networks evolve into the broadband realm, at least in establishing a vision and framework for evolving a nation's telecommunications network to full broadband capability.

Some countries go beyond that position, promoting broadband deployment through national policies in an effort to capture the economic and social benefits of this new infrastructure. Many compare the importance of broadband networks to that of other networks — river and canal systems, roads, railways, and freeways — that knitted their communities together, overcoming barriers posed by distance to their economic, social, cultural, and political life.

The benefits of a broadband-connected citizenry are compelling. The potential for broadband to help deliver public services more efficiently and cost-effectively, particularly in education, healthcare, or public safety and security, especially in remote or rural areas, has led some governments to consider direct or indirect support for broadband deployment as an important element of national development.

One Canadian study, for example, estimated better broadband deployment could yield as much as a 10 percent reduction in healthcare costs, a very significant gain within that country's public healthcare system.[5] The prospect of similar benefits in education as well as the provision of everyday public services — at municipal, federal, and state, provincial, or regional levels — may lead governments to support the roll-out of broadband more actively and aggressively. The 1996 *Telecommunications Act* in the U.S. describes principles of universal service that include broad access to advanced telecommunications services.

The tremendous economic benefits of broadband deployment, combined with the uncertain state of the global and national economies, are leading some industry groups and observers in the U.S. to call for a more proactive approach by the U.S. government to increase broadband subscriptions in the interest of driving innovation in the technology sector, thereby driving more growth. As Red Herring magazine put it, "We need a national broadband policy — a broadband Marshall Plan of sorts. Specifically, we endorse the goal of making 100-Mbps broadband availability to 100 million U.S. homes and small businesses by 2010."[6]

The US Internet Industry Association also endorses the proactive approach. The Association's president and CEO has said, "If the high-speed Internet is essential for the nation's survival, as FCC Chairman Michael Powell asserts, then we need a national policy to support the deployment of broadband. South Korea, which long ago implemented such a policy, has surpassed the US in the number of wired homes and businesses. France has a national policy for broadband already underway. So do Australia, China, and a host of other countries whose vision of the Internet is clearer than our own."

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[5] connecting.canadians, "The Economic Benefits and Challenges of Broadband in the New Networked Economy and Society," Presentation to the National Broadband Task Force, January 11, 2001.

[6] Red Herring, "Broadband needs a Marshall Plan," March 12, 2002.

The Bush administration fully understands the promise of ubiquitous broadband. Addressing the 21st Century High Tech Forum at the White House in June 2002, President George W. Bush said, “This country must be aggressive about the expansion of broadband.”

In discussing the Administration’s policies earlier in the year, Vice President Cheney affirmed, “We also recognize the great potential of high-speed broadband networks to increase productivity and add to growth. The possibilities are tremendous…. As this technology progresses, we're committed to keeping America the world's leader in developing new broadband technology and applications.”

And Nancy J. Victory, Assistant Secretary of Commerce for Communications and Information, has noted on several occasions that “…broadband is an important potential source of growth and investment for our country and for others around the world…. And indeed, the Administration has been taking a number of steps to create incentives for investment, to stimulate demand and usage, and to remove unnecessary government impediments to competition and deployment.”

Governments at all levels can hinder or promote broadband deployment by the policies they adopt. As a technology company, Nortel Networks is especially concerned about the negative impacts that inappropriate regulation can have on product development and the cost effectiveness of solutions deployment. Nortel Networks supports the following principles with regard to public policies as they affect broadband telecom infrastructure:

- Widespread broadband deployment is good for the U.S. and global economies and will enable significant benefits for consumers and businesses.
- Investments in infrastructure deployment won’t be made unless viable business cases can be established.
- Governments should ensure that regulatory policies don’t interfere with the creation of sound business cases and that they are crafted in such a way as to not inadvertently create disincentives to investment, nor should they increase economic risk in a competitive environment.
- Relying on fair competition and marketplace forces is the best way to encourage broadband deployment. Robust competition is good public policy and is good for consumers, competitors, the economy, and business.
- Broadband, no matter how it’s delivered technologically, should be tested in the crucible of a truly competitive marketplace.
- Government policies affecting broadband deployment should be technology neutral, rather than try to pick winners and losers.
- Policies and regulations should be clear, provide the ongoing certainty needed to sustain viable business cases, and ensure widespread availability.
- Sound spectrum management policies are needed to facilitate the proliferation of advanced commercial wireless services.

Global Views on Broadband

This country must be aggressive about the expansion of broadband; we have to. …Hopefully, we're doing a pretty good job of working to eliminate hurdles and barriers to get broadband implemented…. And I'm confident that the [FCC] chairman and the board is focusing on policies that will bring high-speed Internet service, will create competition, will keep the consumers in mind, [and understand the kind of] economic vitality that will occur when broadband is more fully accessible.

— President George W. Bush, Remarks to the 21st Century High Tech Forum, June 2002

In addition to enhancing business efficiencies and broadening commercial opportunities, broadband holds the promise of expanding educational opportunities, improving health care, increasing governments' responsiveness to its citizens, and generally enhancing our global competitiveness. Thousands of new jobs could result from greater broadband deployment, both directly through network construction, and indirectly through industries related to advanced networks and services. Not surprisingly, then, broadband is an important potential source of growth and investment for our country and for others around the world.

As President Bush emphasized last week, "[t]his country must be aggressive about the expansion of broadband." And indeed, the Administration has been taking a number of steps to create incentives for investment, to stimulate demand and usage, and to remove unnecessary government impediments to competition and deployment.

— Nancy J. Victory, Assistant Secretary of Commerce for Communications and Information, Address to European Institute Seminar on U.S. and European Approaches to the Future of Broadband, June 2002

The higher the level of connectivity, the greater the economic benefit. We are at the beginning of this new curve. In the years ahead, advances in broadband, wireless and digital media technologies will open up many new channels of communication and offer greater value and affordability to more people. To grow, we must take full advantage of this connectivity…. But growth will require more than infrastructure. We need to make use of this infrastructure in creative ways to make use of the value that connectivity brings. …the value proposition has shifted from productivity alone, to productivity and creativity.

— David T E Lim, Acting Minister for Information, Communications & The Arts, Singapore, April 2002

…we are now entering uncharted territory. Our copper wires have lain in their ducts or hung from their poles for up to 40 years. And for decades they carried nothing but phone calls. They were simply 'talking wires'. With the advent of the mass market Internet in the 90s, the wires started to sing a little. And now, the broadband Internet promises to transform these same lines into entertainment highways. In other words, the wires are starting to dance.

— Sir Christopher Bland, Chairman, BT, Address to IBTE, January 2002

Oftel's long term aim is to achieve a level of competition in broadband markets that will ensure that consumer and business needs can be met without the need for regulation – ie effective and sustainable competition. There is unlikely to be a 'single solution', whereby broadband is delivered using one technology only. Consumer needs vary greatly and the market is best-placed to decide how, and with which technologies, this can best be achieved.

— David Edmonds, Director General of Telecommunications, Oftel [UK regulator for the telecom industry], Address to Social Market Foundation, April 2002

If the high-speed Internet is essential for the nation's survival, as FCC Chairman Michael Powell asserts, then we need a national policy to support the deployment of broadband. South Korea, which long ago implemented such a policy, has surpassed the US in the number of wired homes and businesses. France has a national policy for broadband already underway. So do Australia, China, and a host of other countries whose vision of the Internet is clearer than our own.

— David P. McClure, president and CEO, US Internet Industry Association

… technological innovations are changing the shape of the Web and pushing the capabilities of the medium. Because of continued online growth, there is a pressing need to upgrade the Web's architecture to a higher IP protocol and explore new online security tools. However, the emergence of widespread wireless Web technology and increased broadband penetration are changing how users think about the Internet and are propelling technological competition.

— The United States Internet Council and International Technology and Trade Associates Inc., The State of the Internet (2001 edition), November 2001

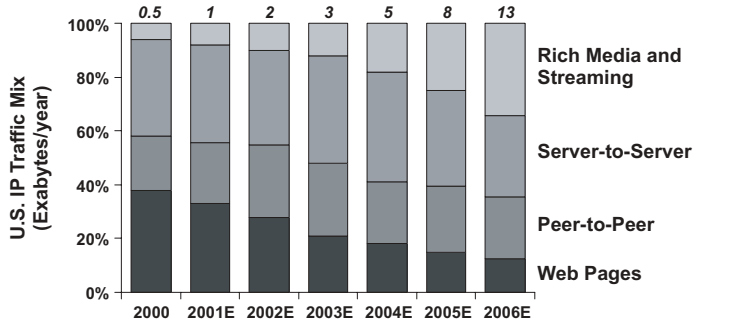
Encouraging Investment

There are high costs associated with broadband infrastructure, both for the carriers deploying it and the technology companies creating it. It's widely recognized that the greatest challenge in realizing the promise of broadband is to stimulate the enormous investments required. As noted earlier, these investments will not be made unless sound business cases can be established in an environment of ongoing regulatory certainty. If they can't, R&D funding will decline, with a negative impact on innovation and the general economy. Productivity gains will suffer and telecom users will lose the benefits that innovative telecommunications infrastructure can generate.

The cost and technical implications of broadband access extend far beyond the access infrastructure required to support connectivity. Delivery of broadband service requires an end-to-end network in addition to the last mile of DSL, cable, wireless, or fiber.

Broadband deployment requires capabilities in the network core to support the additional traffic being carried, increased data storage capacity, and substantially increased content management and control to manage the enormous amounts of multimedia content — video, music, and text — being uploaded and downloaded with new-found broadband access capabilities.

The type of traffic carried across the network continues to change. By 2006, web pages are projected to comprise only 11 percent of the traffic while streaming media may exceed 30 percent.[7] This shift necessitates an end-to-end network capable of delivering "delay" sensitive traffic. The consistently large quantity of server-to-server traffic (machines talking to each other) requires a scalable network with inherent security, reliability, and privacy.



Source: JP Morgan, November 2001

Rich Media and Streaming: audio and video streaming, VOD, corporate broadcasting, video conferencing, video calls, and distance learning

Server-to-Server: Enterprise-owned machines talking to enterprise-owned machines

Peer-to-Peer: Human sending files to other humans (through e-mail or music-sharing applications)

Figure 1 - Shift in U.S. IP Traffic Mix

Common network elements are required for privacy, security, aggregation, routing, switching, optical connectivity, content delivery, content management, web hosting, and storage. Many of these common network elements provide value to the end user beyond pure connectivity. They're a key part of making a resonable business case for the service provider.

Industry must lead the way in making the necessary network investments based primarily on the opportunity to make a reasonable return. Market forces will foster the most efficient and practical network investments. How plentiful investment in last-mile facilities will be depends on the applications to be offered by the connection.

[7] J. P. Morgan, "Telecom Services 2001," November 2001.

Demand for Broadband

According to an FCC report in February 2002, demand for broadband (defined as greater than 200 Kbps in at least one direction) remains strong, with growth in access lines for DSL, cable, and fixed wireless at 36 percent, 45 percent, and 73 percent respectively in the first half of 2001. Demand is being driven by valuable multimedia applications for home and business that enhance personal lifestyle and productivity and stimulate new business models that drive economic activity.

Demand for broadband is largely circular, driven by a continuous cycle of network deployment, application development, and public acceptance. Faster networks generate new applications which, in turn, draw more users to the system, quickly maximizing the network's potential. Adoption increases as content providers innovate and develop new applications requiring more bandwidth and higher speeds.

Increasing Internet usage is an integral part of this circular demand. As Internet penetration increases, demand for feature-rich content increases and demand for higher-capacity networks naturally follows. Broadband connectivity, along with the content and services it enables, has the potential to transform the Internet, both what it offers and how it's used.

Demand for broadband is increasing with the needs of residential consumers, small enterprises, and mobile consumers. Residential consumers are looking for better performance from existing dial-up applications and new applications such as audio-on-demand and streaming video. Enterprises are looking for improved productivity and applications such as video-conferencing, eLearning, e-commerce, and vertical industry applications such as telemedicine. Japan has demonstrated the popularity of mobile data applications by attracting 30 million subscribers to I-mode service. Broadband mobile applications such as video-conferencing and downloading multimedia clips have recently been launched.

Many broad business trends are helping increase broadband demand. There's a move towards virtual business models where enterprises use networks to connect to their partners, customers, and employees. These models can only thrive if the wide area network (WAN) connections between enterprises and their partners are as powerful as their in-building local area network (LAN) connections.

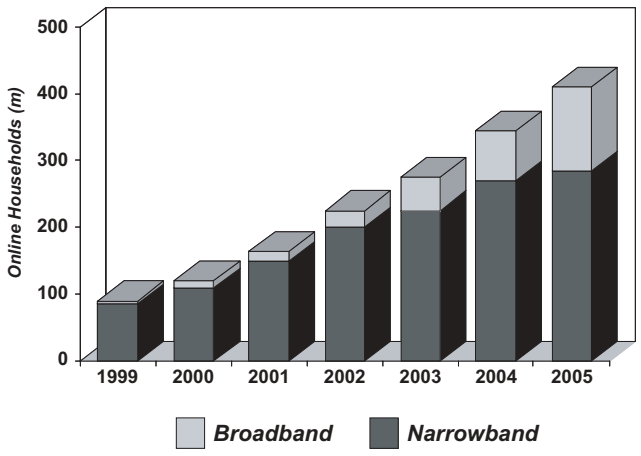


Figure 2 - Growth of Broadband

Source: DSL Forum

As the economy comes to rely on networks for continued growth, "carrier-grade" broadband infrastructure becomes critical. Higher capacity broadband connections are needed to ensure functionality and performance levels as enterprises outsource common business processes, such as payroll or accounting, in order to gain economies of scale normally available only to very large or specialized companies. These connections will provide greater opportunities for small businesses to connect and partner with larger companies (or each other) and open new channels to the best business partners and most profitable target markets. They'll remove barriers of place and distance to hiring talented individuals and provide the flexibility for employees to work at home.

Many other applications currently available or just over the horizon are powering broadband growth. An always-on two-way high-speed connection could be used for:

- interactive applications such as flexible online education programs that offer a rich curriculum, multimedia simulations, continuous assessment, and real-time feedback;
- health applications to monitor a patient's health or support a range of procedures, from accessing medical knowledge to sharing diagnostic X-rays and scans to performing surgery remotely; or
- monitoring home security or home automation systems (heating and lighting, for example).

These types of applications are personally empowering. With access to libraries of information around the world, individuals will have the opportunity to become more enlightened. They'll be freer to be entertained when they want and by a greater selection of material. They'll be freer to choose where they live because broadband will provide them with the means to work, shop, learn, play, and be treated medically over any distance. With access to global online communities, they'll be able to build relationships unhindered by cultural boundaries or physical borders.

The value these applications and services deliver will be the key to greater broadband adoption. As of early 2002, there were 46 million dial-up Internet users in the U.S. paying between $15 and $25 per month.[8] According to a survey of dial-up users, 18 percent cited "lack of need" as the reason they hadn't signed up for broadband.[9] The challenge is to demonstrate to such users the advantages of migrating from narrowband to broadband services that cost $45 to $50 per month.

Education will play a big part in addressing this issue. A survey of dial-up users by the Information Technology Association of America found that 44 percent "would" and 17 percent "definitely would" purchase high-speed services after learning about the features that would be available to them.[10]

This supports surveys by J.D. Power and Jupiter Media Metrix that found users gain value from switching their Internet usage to broadband and that after people make the switch, their Internet behavior changes. Online time increases by about 25 percent and they're more likely to use a variety of online services — downloading music, listening to online music, watching video, or conducting personal banking and stock-related activities.[11] High-speed Internet usage accounted for more than half the time spent online in January 2002, outpacing dial-up Internet access for the first time.[12]

The many applications that will exploit the technological capabilities of broadband to best advantage have yet to be developed. New "killer" applications will emerge as the broadband revolution unfolds. The desire for affordable broadband is already strong enough to encourage new innovation, however. User numbers are becoming large enough to encourage major media and technology providers to create and make available broadband-specific offerings and applications. Infrastructure companies are creating platforms that make it easier for third parties to develop and deploy services that integrate with broadband networks.

The move to broadband will continue to gather strength until service availability, consumer adoptions, and applications combine to power its take-off as a mass medium.

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[8] CyberAtlas, "Life in the Slow Lane is Just Fine," November 2001.

[9] Forrester Research, "Devices and Access Across North America," February 2002.

[10] The Information Technology Association of America, "Building a Positive, Competitive Broadband Agenda," October 2001.

[11] CyberAtlas, "Life in the Slow Lane is Just Fine," November 2001.

[12] Nielsen/NetRatings, January 2002.

The Convergence of Enabling Technologies

Broadband has now become a viable opportunity because many technological and other developments underpinning its deployment are converging, the major ones including advances in network cost performance, digitization and storage, carrier-grade networks, network intelligence, and new access appliances. These developments, initiated in various industries, enable the market readiness and adoption of broadband in both public and private networks.

- Network Cost Performance The cost to carry a data bit across the network has decreased dramatically in the last few years. In 2000, RHK Research estimated cost per gigabit per second (Gbps) would decrease from $210 in 1994 to $4 in 2001.[13] Improvements in fiber-optic and data-switching technologies have resulted in higher data network speeds at lower unit costs, with consumers already benefiting from the resulting lower long-distance rates and competitive data-transport prices.
- Digitization and Lower Storage Costs Enterprises continue to create and share information necessary to run their businesses in disk drives and servers. Individuals continue to create huge amounts of data in the form of photographs and home videos, much of which still remains in analog magnetic tape but is transitioning to digitization with the popularity of digital cameras. The store of text, video, and music continues to expand, making a huge library of content available. Continued improvements in storage technology and costs facilitate this growth, with the cost of storage falling from about $1/megabyte in 1999 to 30 cents in 2001 estimated on its way to no more than a penny by 2005.[14]
- Carrier-Grade Networks Both adoption rates and the ability of service providers to provide profitable network services will depend on the building of carrier-grade broadband networks with key fundamental attributes. The network has to be reliable (available when you need it), secure (information for intended audiences only, systems secure from hackers), evolvable (leveraging current invested assets when implementing the next-generation solutions), scalable (the network can grow cost-effectively without performance degradation), manageable (network performance, service delivery, and user parameters can be managed), and multi-service (service agnostic from e-mail through to multimedia). These attributes are necessary for content providers and end users to trust the network enough to adopt broadband for critical business and personal use. They're necessary so service providers can deliver value customers are willing to pay for and to engender mainstream use.
- Network Based Intelligence Network functionality can be extended with intelligence technology that enables a significantly higher level of security, performance, efficiency, agility, and differentiated service levels. Intelligent network services include firewalls, intrusion detection, virus scanning, traffic control, load balancing, content filtering, bandwidth management, and content delivery. The result is networks that are user aware, application aware, and resource adaptable. Many of these technologies are available today.
- Variety of Access Appliances The introduction of a variety of fixed and mobile access appliances designed for specific needs will also promote broadband adoption by allowing people to access information where they want to or more pervasively through a multitude of devices and at lower costs than through PCs.

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[13] RHK, 2000.

[14] Business Week Online, "Online Extra: EMC: Time to put your Money in Storage?," June 18, 2001.

The Next Step in Network Evolution

Network operators and enterprises are now adopting the optical, wireless, and Internet technologies they need to manage growing volumes of data traffic flowing onto an expanding number of communications devices. Networks are gaining greater intelligence, extending their capabilities beyond transporting and routing. Innovative technologies are making the Internet aware of the applications, users (and their personal preferences), content, resources, and the nature of the traffic it's carrying. These capabilities improve network performance and security, reduce costs, and create a more personalized experience for the user.

Network operators can leverage their infrastructure to create converged networks supporting data, voice, video, audio, and broadband applications. The multiple networks of the past are becoming converged networks that are more intelligent, cost-efficient, and easy to manage. One manifestation of this convergence is the transition of voice services from circuit-based networks to packet-based networks.

This is a major step in the evolution of networks, which has been accelerating for several years as networks have propagated at an ever-increasing rate. In the 1990s, when nourished by steady flows of capital, fiber-optic networks, data networks, wireless networks, cable networks, satellite networks, and the Internet spread rapidly within countries and around the world. They continue to grow very quickly, becoming more intertwined and interconnected every day.

The information available to be tapped within this global network mesh is becoming richer and richer, acquiring greater variety and depth as it becomes much more abundant. All this information is flowing through the available network conduits at extremely powerful, fast, and accelerating rates.

Large companies and other organizations have for several years had the wherewithal to access this information through T1 lines or other high-performance access technologies. These organizations have learned how to harness the power of information flows to help them innovate and reshape their businesses.

Such powerful access technologies, however, are generally so expensive as to be beyond the ability of individuals or small or medium-sized businesses to afford. That's why first-generation and then more innovative broadband technologies must be deployed to meet the needs arising in these market segments. But many factors beyond technology — such as valuable applications and broadband availability — set the pace for broadband deployment.

The Communications Infrastructure of Tomorrow

As various stakeholders — corporations, government groups, and agencies — work toward making appropriate decisions to meet the broadband challenge, they should consider that in the not-so-distant future, networks will be built that far surpass the capabilities envisioned in today's broadband deployment discussions.

This will be a future when networks will have not so much been transformed as transfigured. These networks will provide infinite bandwidth available on demand and always-on wireless access, both services available to everyone in the world at ultimately affordable prices. This signals a fundamental change in how networks deliver multimedia content and how people receive and interact with it.

The migration to this next generation of networks naturally involves constructing larger connections to homes and medium-to-small businesses so much greater volumes of data bits can flow faster, freely, and cheaply. It also involves building very high-speed, high-performance networks that support everything from streaming media to global text retrieval to enhanced telephony services. Most of all, it involves making sure people can access high-speed flows of information without being hooked up to a wire. Always-on wireless access through a multitude of new devices will be a crucial component of tomorrow's networks.

To move beyond today's broadband into the era of infinite bandwidth and always-on wireless access, many breakthroughs and investments will be needed in key areas, including optical technology, high-spectrum communications, wireless, and high-performance network infrastructure. But from the network core outward, progress is being made today on setting the foundation for networks capable of delivering these key attributes.

Next-generation optical systems designed to redefine the architecture of network backbones, for example, are revolutionizing network economics. The speed and capacity of optical backbones are becoming available in urban centers and to more and more small and medium-sized businesses. As these metro networks expand, network congestion will be relieved and both enterprises and service providers will be able to expand their capabilities with multimedia services and new applications. Wireless multimedia communications are also becoming more widely available and mobile networks are delivering more services to a broader range of mobile devices.

Network advances in each of these areas are generating cost savings, value-added capabilities, and significant benefits for end users at home and at work.

Ultimately, we'll be able to receive any amount of personalized information we want, in any form we want, at any time and in any place. We'll be able to tap into an all-pervasive bit stream — a digital stream of video, audio, text, and images — with the ease and simplicity of flipping on a switch to light up a room. When these networks are in place, we'll expect communications capacity — bandwidth — to always be there in abundance, like electricity or dialtone or the air we breathe.

Just as electricity and the telephone in the last century redefined what business gets done, reorganized how business gets done, and recast domestic and social life, so the networks delivering infinite bandwidth and always-on wireless access will influence everyday life in hundreds of ways, large and small, and will have a huge impact on business innovation, efficiency, and productivity.

As a technology company that's played a major part in almost every significant advance in communications capability in the U.S. and globally for more than 30 years, Nortel Networks knows these networks will be built based on sound market economics and the great value they'll bring to national economies and global society.

Appendix: An Overview of Broadband Delivery Today

There are four prominent access technologies that deliver broadband connectivity, offering the high-speed and always-on access that enables broadband applications such as audio-on-demand, videoconferencing, and eLearning. They are: digital subscriber line (DSL), cable modem, wireless, and fiber. Each offers various levels of speed. To compare:

- Typical dial-up speeds range from 2.4 to 56 Kbps.
- Cable modems and ADSL provide data rates of 300 Kbps to 1.5 megabits per second.
- Fiber can scale to gigabit-per-second rates.
- 2G wireless supports up to 14.4 Kbps while 3G promises up to one megabit per second.

Access Providers

The primary providers of access services are cable operators, incumbent local exchange carriers (ILECs), competitive local exchange carriers (CLECs), and wireless companies with licenses for mobility, PCS, satellite, and fixed wireless (MMDS, LMDS) services. Internet service providers (ISPs) offer dial-up Internet access today and many offer broadband data. Many incumbent exchange carriers (IXCs) are also planning broadband services.

These companies have made significant investments in infrastructure, both in access technologies as well as the upgrades and enhancements to other parts of the network required to deliver broadband services.

- Cable operators have made significant investments in upgrading their hybrid fiber-coax (HFC) infrastructure to be bi-directional and capable of supporting cable modems.
- ILECs have made significant investments to condition their copper infrastructure to support DSL.
- Mobility and PCS providers have invested in 2G technologies and are looking to upgrade to 3G technologies for broadband applications.
- IXCs and ILECs have invested heavily in optical infrastructure in the backbone and are extending that investment into the metro.

All recognize that much more money will have to be invested in broadband infrastructure to expand availability and improve capabilities. Whether these investments are made will depend on each business case, the market's preference for the different technologies, and the prospect of achieving a reasonable return on investment.

Applications Fueling Broadband Growth

E-mail was one of the initial "killer" applications of the Internet. It's accessible whatever the connection speed. But as the size of attachments and the sophistication of e-mail applications increase and more multimedia graphics are embedded into e-mails, broadband access becomes a practical necessity to improve ease of use and functionality. Similarly, the use and efficiency of wireless short-message service, which is widely available in today's 2G systems in Europe and Asia, will be greatly improved with 3G systems.

Business Applications By being always-on and faster, broadband access improves productivity for all enterprises, especially the under-served small-to-medium-sized businesses. Applications such as videoconferencing, eLearning, telemedicine and teleworking require broadband.

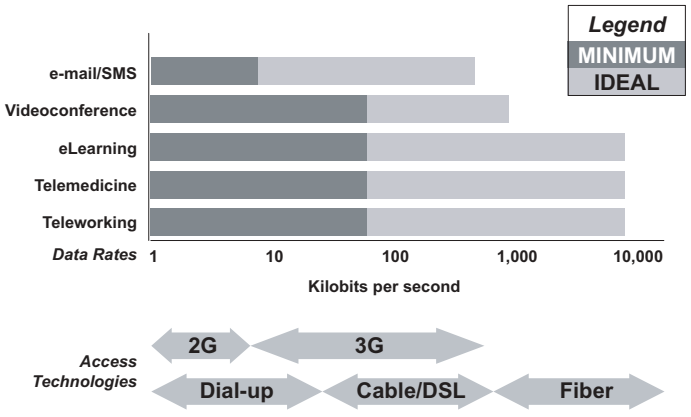

Figure 3 - Sample Business Applications and data rates
Source: National Broadband Task Force Report and Nortel Networks estimates

- There's a move to more virtual businesses, with greater outsourcing of business processes and with enterprises connecting to many suppliers via online e-commerce systems.
- Many employees now work from home a day or two a week.
- Broadband improves opportunities for partnerships between small and large enterprises and the targeting of profitable markets.
- Broadband increases the ability to hire talented individuals without regard to barriers of location.

Residential Applications There are a number of trends increasing the need for broadband connections to homes. Digital cameras, for example, are becoming increasingly popular, having penetrated 12 percent of U.S. households in 2001 and with 20 percent compounded annual growth rates expected through 2005.[15] Microsoft Windows XP simplifies the manipulation of digital images directly on the desktop. HP's Instant Share technology allows users to mark photos for printing, saving to a file, or delivery to up to 14 e-mail addresses automatically when the camera is connected to the PC. Broadband mobile applications such as picture messaging, mobile Internet access, videoconferencing, and multimedia downloads have also proven popular in Japan.

[15] CreditSuisseFirstBoston, "Pixels and Profits," January 2002.

Popular residential applications in use today and expected in the near future can function across a variety of access technologies at a variety of connection speeds. But connection speed does affect range of functionality and ease of use.

- Applications such as eBanking, eGaming, eNews, home shopping, and digital photo sharing are tolerable with dial-up access, but are more ideally served with broadband.
- Four to 10 megabits per second will be needed to deliver standard definition TV.
- HDTV and fully interactive TV would require even higher throughputs of over 10 megabits per second.

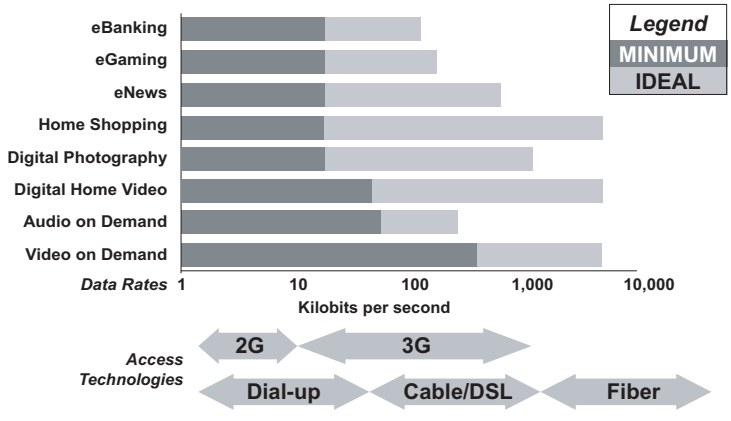

Figure 4 - Sample Residential Applications and data rates
Source: National Broadband Task Force Report and Nortel Networks estimates

"Killer" Applications The "killer apps" are not clear today, but it's common in any communications revolution that the "killer" application that makes things take off tends to be unknown or unheard of at the outset. Research and development will generate the "killer apps" for broadband.

- Software could enable real-time correlation of relevant data such as Mapquest, current location, and a real-time traffic report to avoid traffic jams.
- Software translators are emerging, allowing for the sharing of information across multiple enterprises.
- Smarter search engines will access, search, and use information from any source, allowing, for example, a medical research firm to collect and correlate drug test data from every available source.
- A large number of PDAs that support broadband applications will become available.
- Video file sharing could become a common application.

Nortel Networks is working with Northwestern University in the U.S. on several high bandwidth applications, which can lead to new business models and new productive business processes.

- 3D virtual reality
- 3D mobile imaging without special glasses
- Massive parallel computing
- 3D teleconferencing

- Distributed industrial design
- Remote medical imaging and analysis
- Storage on demand

Some of the innovative broadband services being enabled on Nortel Networks server platforms include personalized multimedia services such as “click to dial” integrated voice, video, and text chat, collaboration and application sharing, personal call manager, and unified messaging, transport, and personal directories.

Technology Options

DSL

Digital Subscriber Line (DSL), a maturing technology that’s been around for several years, leverages traditional telephone networks to offer the high-speed, always-on access that enables the delivery of broadband applications.

Telephony networks were designed for high-quality voice, emergency communications (E911), and dial-up access. With the demand for broadband, ILECs and CLECs have been active with standards bodies to standardize various forms of DSL, including asymmetric DSL (ADSL) which allows for variable up and down link speeds in retrieving or sending information, with rates typically between 300 Kbps and 1.5 Mbps.

DSL uses different frequencies than voice on the same copper loop to the home, taking advantage of capacity in the copper wire not used for voice. A DSL modem is needed at the home and DSL Access Multiplexer (DSLAM) is needed at the central switching office or a Digital Loop Carrier (DLC) closer to the neighborhood. ILECs have invested to condition the copper loop and upgrade DLCs so they’re able to support DSL.

DSL service is limited by distance. A subscriber within one mile of the DSL access equipment might achieve one megabit per second while a subscriber two miles away might achieve 300 kilobits per second. More investment is needed to ensure that a high-speed rate can be offered to all customers within a serving area.

CABLE

Cable broadband access solutions have been primarily directed to residential subscribers since they use the same cable network that has traditionally provided television service.

Cable TV has traditionally been strictly one-way (from the cable company into the home), so technical modifications have had to be made to the cable network to provide two-way high-speed Internet connectivity. Two-way units that can handle data traffic going in both directions have replaced one-way signal amplifiers throughout the system. Special boxes are installed at the subscribers' premises to separate upstream (to the cable company) from downstream (to the home) traffic. A cable modem is installed at the customer's premises to connect the network to the computer.

Upgrades to cable networks allow the sharing of broadband access bandwidth up to 36 million bits per second (Mbps) per “channel” depending on the modulation scheme. Cable companies can dedicate more channels to increase the total available bandwidth. Shared upload bandwidth can be as high as 10 Mbps. In practice, individual users experience

transmission speeds ranging from several hundred Kbps to 1.5 Mbps or more. Both television signals and data are carried by a combination of fiber-optic and coaxial cable, known as hybrid fiber coax (HFC).

Besides being able to deliver television (both analog and digital) and broadband Internet access, cable networks are being augmented to also support voice services. This service combination allows multiple or "converged" services to be supported by a single service provider.

Today's cable networks are "shared networks," originally and optimally designed for broadcast-type television services. For broadband Internet access, users access a common network, analogous to a local area network (LAN). Access speeds can decrease during peak usage hours when many customers are sharing bandwidth and, similarly, can be completely available to a single user in off-peak periods. This network sharing has also led to security concerns and fears that hackers might be able to eavesdrop on a neighbor's Internet connection.

Given the high bandwidth capacity of coaxial cable, broadband delivery over cable has a good opportunity to improve its performance with future advances in technology.

WIRELESS

The growth of wireless subscribers worldwide has surpassed all expectations. Given its ubiquity, flexibility, and ability to be deployed quickly, wireless is already the primary form of communications in many countries.

Forrester Research predicts there'll be more than 120 million mobile subscribers with both voice and data in the U.S. by 2006.[16] Broadband wireless (3G) will comprise approximately two-thirds of that number, penetrating almost 30 percent of the population by 2006 and rivaling the penetration of fixed connections.

Multiple bands of wireless spectrum can be used to provide high-speed broadband access, with licenses allocated to companies delivering cellular and PCS, satellite, MMDS, LMDS, and wireless LAN technologies.

Cellular and PCS (Personal Communications Systems) In most countries, two licenses have been issued for cellular phone service in the "A" and "B" band, with typically two to four licenses issued for the PCS bands.

The next network transformation for wireless involves the 3G technologies of CDMA 2000 1X and UMTS, which will also mean significant network cost reductions. The network's utility will increase as well, as it becomes the platform for "always-on" high-speed mobile-data applications. Innovation is also occurring in the core of the network as circuit switching evolves to enable the end-to-end packet networks required for 3G.

3G promises data rates in the range of 100 Kbps to one megabit per second, which will enable broadband wireless applications. Video pictures can be downloaded in 2.1 seconds versus 23 minutes with 2G technologies. Web pages can be downloaded in less than a second versus 30 seconds with 2G technologies.

Mobile voice services have cannibalized local fixed voice service. 3G will both compete with and complement fixed broadband technologies in much the same way. Consumers will choose tradeoffs of mobility and slightly lower quality versus very reliable but fixed networks.

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[16] Forrester Research, "Sizing US Consumer Telecom," January 2002.

Satellite Two-way high-speed Internet access via satellite is being offered as a niche play by a few operators. Data rates are typically 400 to 500 kilobits per second and target areas are typically rural.

Satellite video broadcast providers can provide high-speed downloads through the satellite link but typically require a dial-up uplink. A second antenna would be required to deliver high-speed access to residences that already have satellite-based video.

The next generation of satellite systems, due in orbit in 2002, will offer higher data rates and much higher system capacity.

MMDS Multi-point microwave — or multi-channel, multi-point — distribution service (MMDS) is a broadband wireless (line-of-sight) point-to-multi-point communication system located in the 2.1 GHz to 2.7 GHz bands. MMDS has been used around the world for more than 30 years to provide a one-way, *analog* wireless broadcast service. As such, the MMDS industry has been more widely known as the wireless cable industry.

With the advent of the Internet and the use of digital technology, MMDS is now seen as a possible broadband-service-delivery option. MMDS providers, primarily in the U.S., are upgrading their networks to create interactive Internet-access capability, addressing residential demands for broadband digital data and TV. MMDS represents a very small portion of Internet access today.

LMDS Local multi-point distribution service (LMDS) is another broadband wireless (line-of-sight) point-to-multi-point communication system. It operates above the 20 GHz band (depending on country of licensing). It's a digital system by design and can be used to provide two-way voice, data, Internet, and video services. In the U.S., LMDS occupies the radio spectrum from 27.5 to 31.3 GHz.

Many telecom vendors have developed a full portfolio for the LMDS band and are actively marketing the equipment to service providers. Lack of equipment standards has been a problem, in terms of ensuring interoperability and keeping costs down, affecting LMDS' market success. As with MMDS, LMDS represents a very small portion of Internet access today and is limited by line-of-sight radio design issues such as terrain and rainfall.

Both MMDS and LMDS are alternative technologies to DSL and cable where accessibility to those capabilities may be restricted, such as in rural areas beyond the reach of DSL or cable.

Wireless Local Area Networks (LANs) There's growing interest in wireless LAN technologies, such as Bluetooth or 802.11B, for short-range high-speed access in public places such as airport lounges and coffee shops. In early 2001, Starbucks announced its intention to deploy 11-megabit per second wireless LANs in all 3,000 of its U.S. retail outlets. Many CIOs have expressed interest in wireless LAN technology, which could also have a future in home networking.

FIBER

Service providers and enterprises have deployed fiber for many years, primarily to transport voice and data services over long distances, interconnect service provider facilities, and connect enterprise locations. Fiber is deeply entrenched throughout the telecommunications infrastructure, except for the local access network.

Connecting residential subscribers to the network with fiber has been tried out in many forms over the years — fiber to the user, fiber to the building, fiber to the curb, fiber to the home. Fiber is considered to be an excellent future-proof technology that potentially offers the highest levels of speed, reliability, and longevity for broadband delivery. Fiber provides a very resilient architecture that can scale in response to increasing bandwidth-intensive applications and services.

Innovations and widespread deployment have resulted in technology and cost efficiencies. These, in turn, have fueled fiber's advance into metropolitan areas, connecting enterprises with new services such as optical Ethernet, which marries the simplicity of the well-understood Ethernet LAN protocol and the reach of optics and can be deployed over various optical architectures. They've also fueled fiber's push into suburban networks supporting remote voice switching equipment. As applications develop and economics improve, fiber is moving closer and closer to the end user. Fiber penetration of small businesses may still be modest, but Infonetics expects that optical will be the Internet access technology of choice for 20 percent of medium-sized businesses and 25 percent of large businesses by 2006.[17]

Cable and DSL

To date, cable modem and DSL have proven to be the main technology contenders in the marketplace. Worldwide DSL and cable modem subscriber bases were 16.6 million and 14.4 million, respectively, in 2001.[18]

In the United States, where cable TV penetration is higher than in other parts of the world, the DSL and cable modem subscriber bases were estimated at 4.4 million and 7.3 million, respectively, the same year.[19]

In the United States, about 45 percent of households can purchase DSL service, while 70 percent can order broadband over cable.[20] Currently, only 12 percent have adopted high-speed access service.

Other developed countries have a similar rate of residential fixed broadband adoption. In Europe, broadband penetration rates varied from two percent to 10 percent in 2001, and are estimated to grow to an average of 20 percent by 2006, with a range of 15 to 30 percent depending on the country.[21] The exception is South Korea, whose unique conditions of high standard of living, urban concentration, 25 percent lower broadband access costs, and metered phone service have already encouraged broadband penetration to 35 percent of households by the end of 2001.[22]

In a recent survey by Forrester Research, 47 percent of dial-up consumers cited price as the top reason they hadn't signed up for broadband service.[23] Accordingly, many service providers are considering changing their high-speed access pricing from a flat fee with an all-you-can-use structure to tiered pricing, with lower fees for 'light' users and higher fees for more active users.

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[17] Infonetics Research, January 2002.
[18] Dell 'Oro Group, January 2002.
[19] Jefferies and Company, Inc., February 2002.
[20] The Information Technology Association of America (ITAA), October 2001.
[21] The Yankee Group, January 2002.
[22] Dell 'Oro Group, January 2002.
[23] Forrester Research, "Devices and Access North America," February 2002.

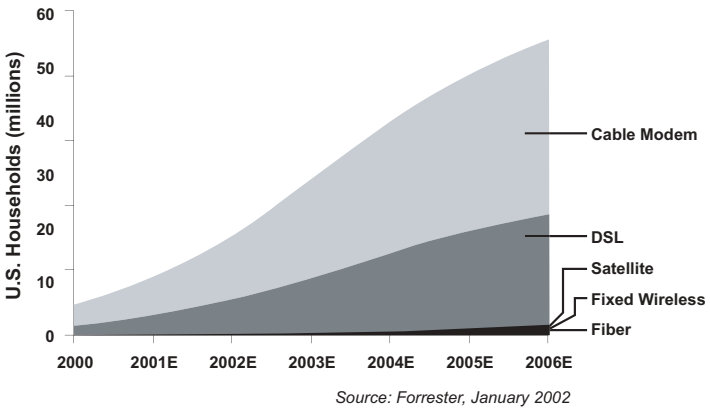

Figure 5 – Forecast of U.S. Household broadband access technologies

In the same survey, 24 percent of consumers cited "not available in my area" as their second reason for not signing up to broadband. Significant investment is needed to improve availability and network performance. Market forces will increase penetration via increased functionality, new applications, extended coverage, or changes in pricing.

To achieve a reasonable return on investment, many service providers are looking to provide complete broadband service, offering more than connectivity with differentiated services such as security, content delivery and personalization, web hosting, and storage.

Cable modem and DSL are projected to be the prominent broadband access technologies to residences, with cable modems continuing to have a larger share of the market, at least in the U.S. With slightly over 100 million households in the U.S., broadband penetration could exceed 50 percent by 2006.[24] Cable modem and DSL provide sufficient downstream speeds for much of today's broadband content, but content is increasingly feature-rich. Content such as integrated messaging, video and music streaming, virtual and interactive gaming, video telephony, and enhanced TV (Internet/digital/interactive/high-definition/video-on-demand) may require bandwidth beyond what cable or DSL can deliver.

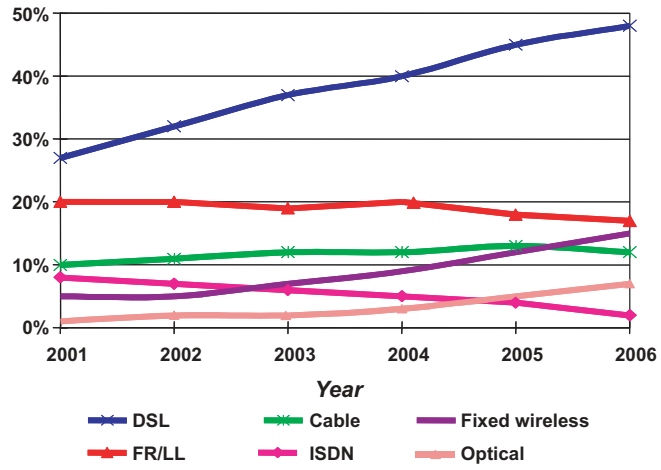

Figure 6 - Forecast of U.S. Small Businesses broadband access penetration

Source: Infonetics Research, January 2002
Based on a survey of 600 companies of 20 to 100 employees

Many access technologies will compete for small business, including DSL, followed by frame relay/leased line, cable, fixed wireless, and optical. Some businesses may have more than one access method, matching functionality with requirement, due to the varying needs of multiple offices. Continued innovations will further the deployment of fiber into metropolitan areas connecting enterprises with new services such as optical Ethernet.

[24] Forrester Research, "Sizing US Consumer Telecom," January 2002.